U.S. Army Research, Development and Engineering Command

Advancements in Personnel Incapacitation Methodologies for Multiple Cartridge Projectiles (MPCs)

NDIA – Joint Armaments: Conference, Exhibition, and Firing Demonstration

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Outline

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      - MUVES-S2
      - Modeling MPCs
      - ORCA
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- Analysis example
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- Operational modeling
- Questions

Background – CIAP Study

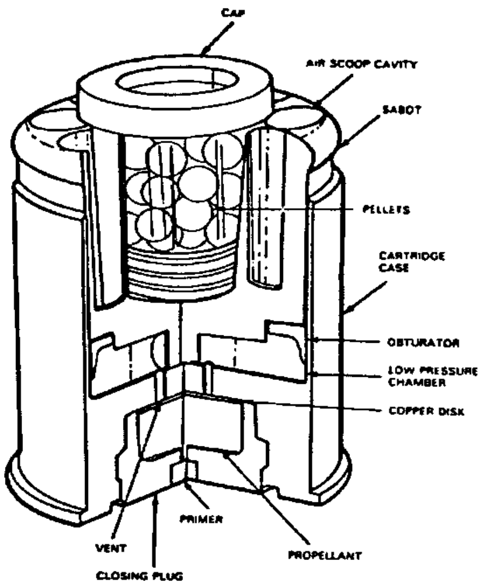
- The intent of the CIAP program is to replace the current 40mm Multiple Projectile (M576) cartridge with modern alternative.

- ARL conducted a 3 phase effort to assist in the design:

  - Phase 1 – Characterize the M576
  - Phase 2 – Characterize the Mossberg 590A Tactical Shotgun System w/ standard configuration
  - Phase 3 – Concept evaluation and optimization

- Each phase considered:

  - Pellet mass/velocity/quantity
  - Pellet shape and in shot dispersion
  - In addition, as a part of phase 2, ARL evaluated and compared the Probability of Incapacitation (P(I) =1) values of the M576 and the 590A



Cutaway View of the M576

Mossberg 590A

All modeling and simulation were performed with ARL-SLAD's MUVES/ORCA software

Overview of Modeling MPCs

Modeling is composed of three stages:

- Delivery
- Damage to target (injury)
- Incapacitation (assessment of target's reduced capability to accomplish tasks)

Hit a Target

Target posture
Aim point
Aim error
Trajectory
Velocity decay
Air drag
Dispersion

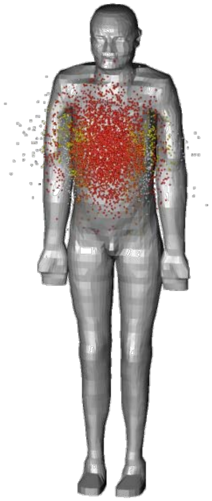
Delivery

Injury

Hit location
Shot line in target
Striking velocity
Fragmentation effects
Anatomical model
Deleterious processes
Tissue retardation
Resulting hole sizes

Damage to Target

Task-based Assessment



Assess target's reduced ability to accomplish tasks, using Operation Requirement based Casualty Assessment (ORCA)

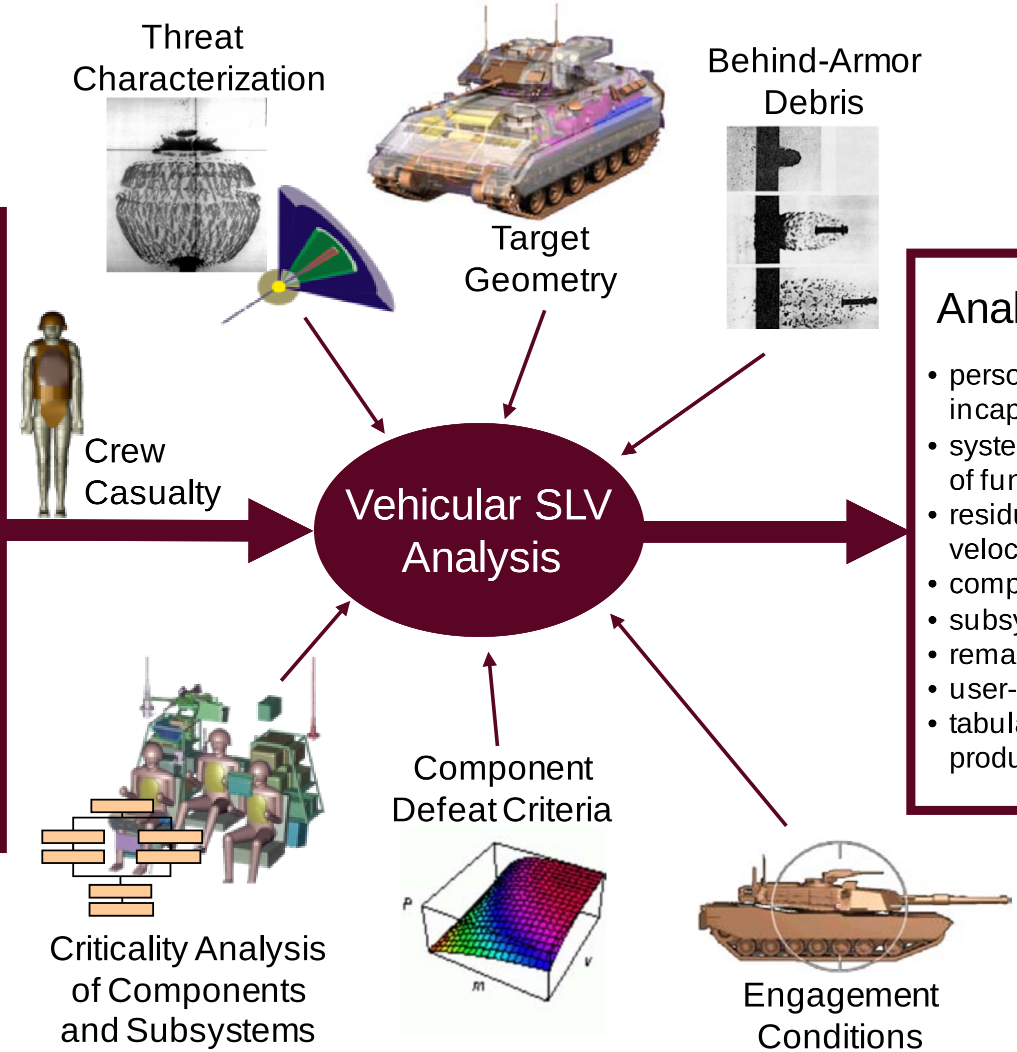
Incapacitation

MUVES-S2 with Embedded ORCA

A Survivability/Lethality/Vulnerability (SLV) computer model capable of analyzing the effects of one or more munitions against aircraft, ground-mobile targets and/or personnel

ORCA Methodology
allows for:

- discrete shot lines through anatomy based on orientation of threat trajectory to personnel
- projectile penetration mechanics through various anatomic structures
- velocity retardation of threat through wound track
- injury description by type, severity, and frequency
- in-depth description of operational effectiveness



Analysis Outputs

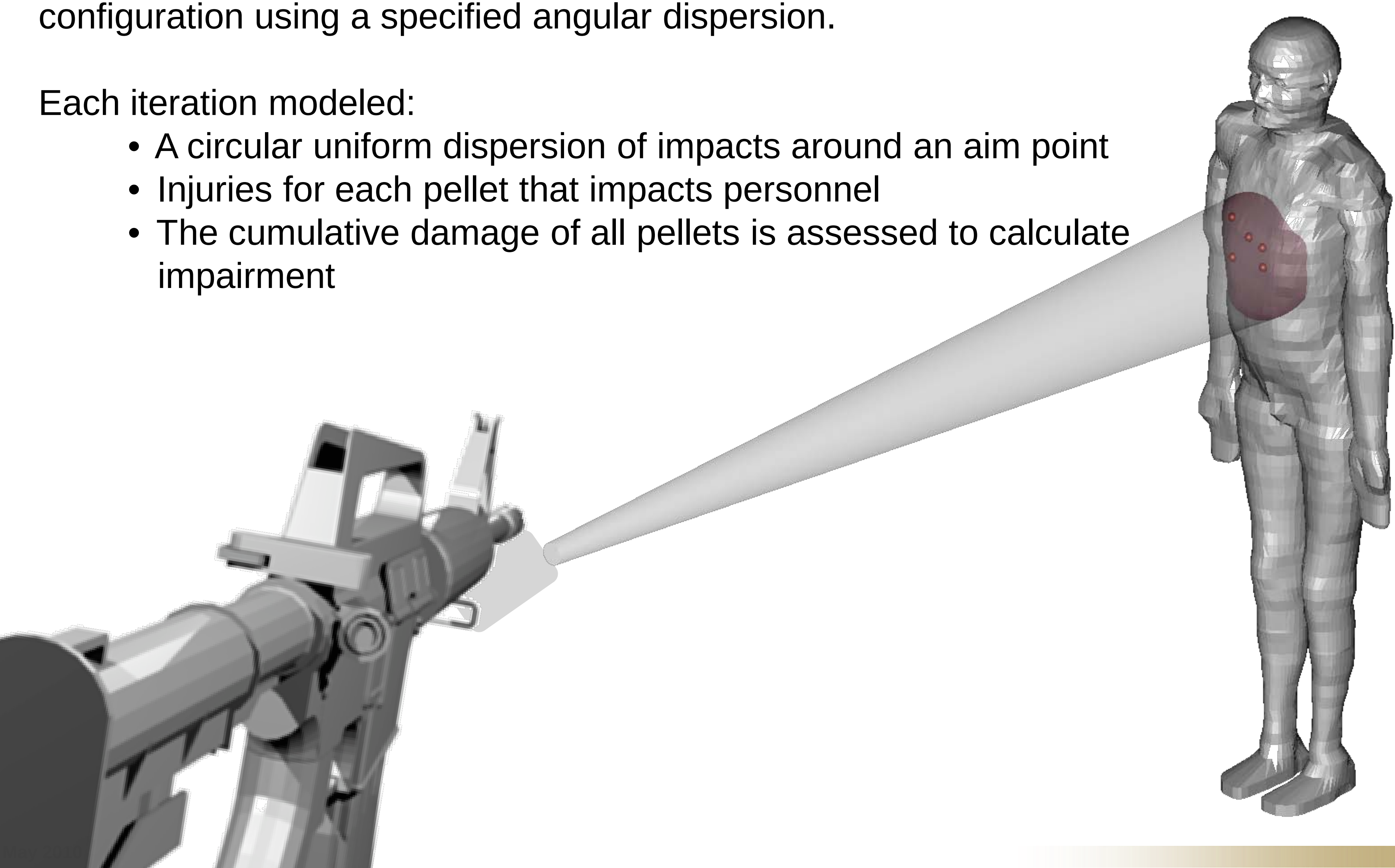
- personnel injury and incapacitation
- system-level kills / loss of function
- residual penetration & velocity
- component damage
- subsystem capabilities
- remaining system utility
- user-defined criteria
- tabular & graphical products

How MPC's are modeled in MUVES-S2

Each run within MUVES-S2 modeled 250 iterations of a unique shot configuration using a specified angular dispersion.

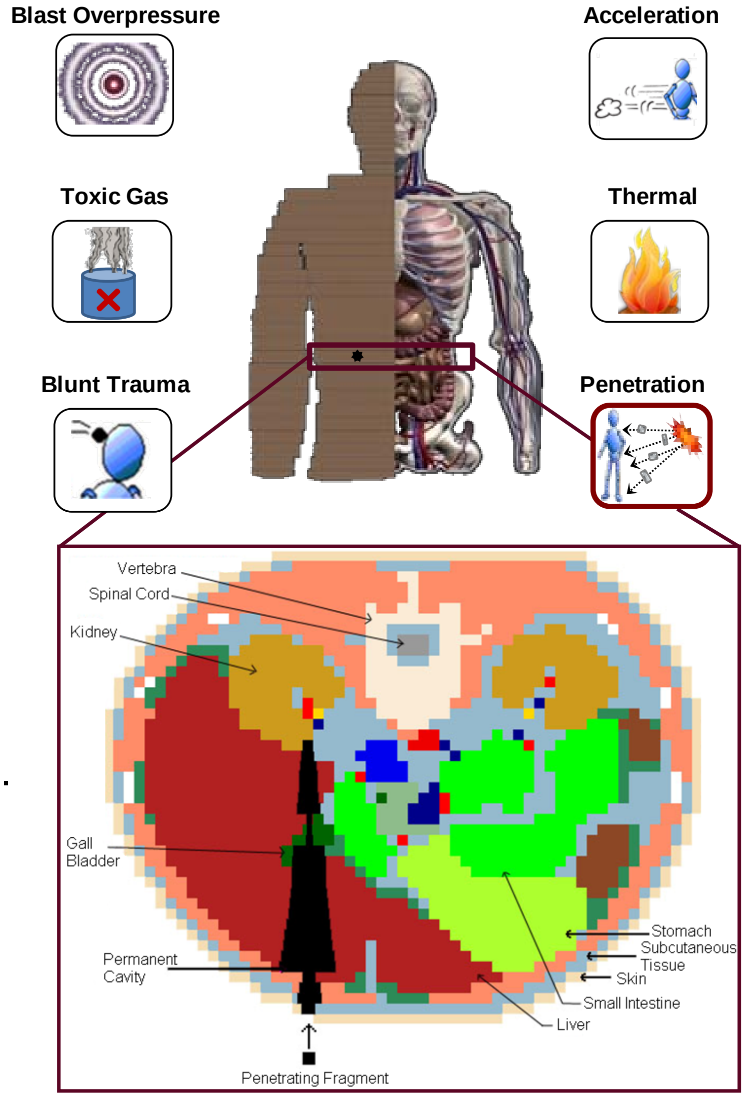
Each iteration modeled:

- A circular uniform dispersion of impacts around an aim point
- Injuries for each pellet that impacts personnel
- The cumulative damage of all pellets is assessed to calculate impairment

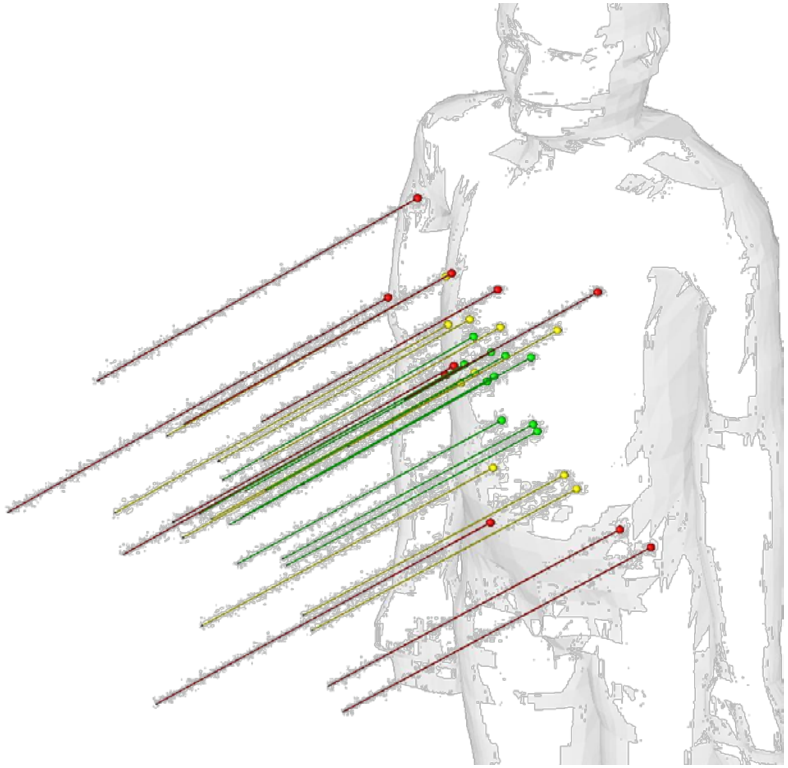


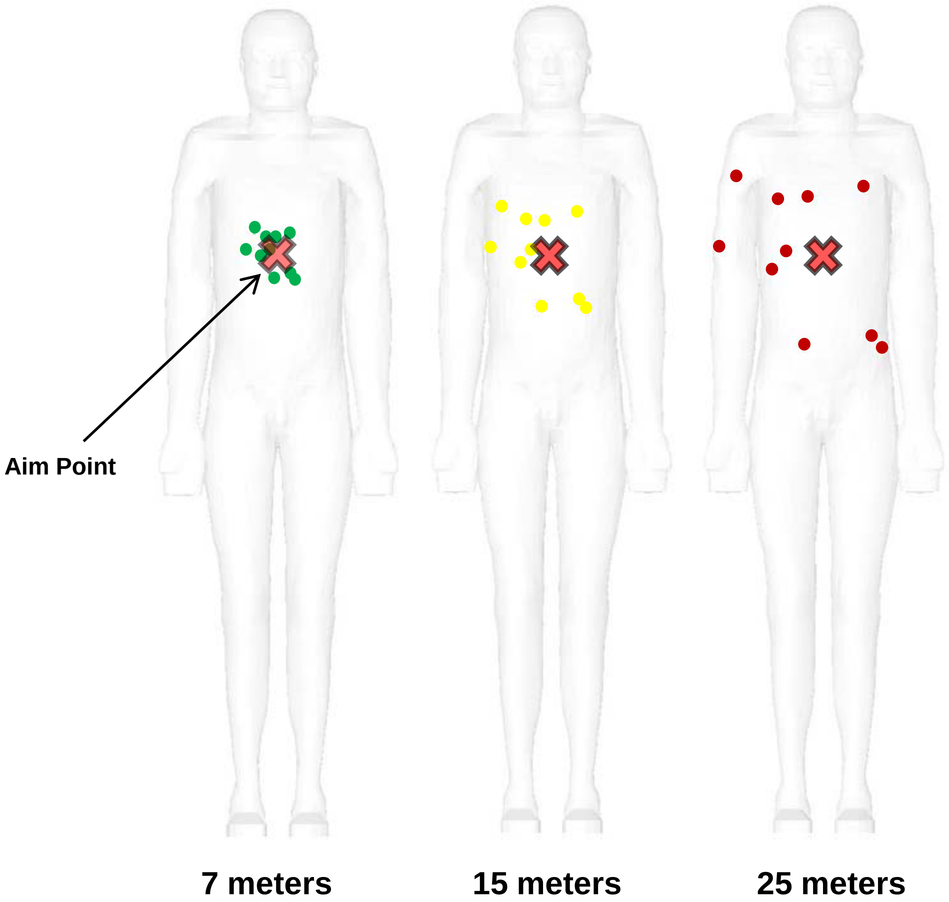
Operational Requirement-based Casualty Assessment (ORCA)

- ORCA is a high-resolution computerized human vulnerability model that is used to assess the impact of various casualty-causing insults on personnel.
- ORCA calculates several injury severity trauma metrics that may be used to characterize both an individual injury as well as multiple injuries to a single person.
- Incapacitation:
  - The inability to perform, at a level required for combat effectiveness, a predefined combat role at a specific time after wounding:
    - Physical capabilities
    - Mental capabilities
  - A combat role is a specific list of individual tasks that personnel must be able to perform at a pre-designated level.
  - Personnel are considered incapacitated if they cannot perform their given combat role at the minimum capability level, and are considered an **Operational Casualty.**



Sample Dispersion Patterns





Potential dispersion patterns at given ranges

Dispersion provides the means for MPCs to affect damage to multiple critical tissues at once but diminishes the incapacitation potential of a cartridge when it causes an insufficient number of projectiles to impact the target.

Example of a Target Profile

Target Profile: Insurgent
Armor: Light to none
Environment: Close quarters
Capabilities:

- Stand
- Aim
- Shoot

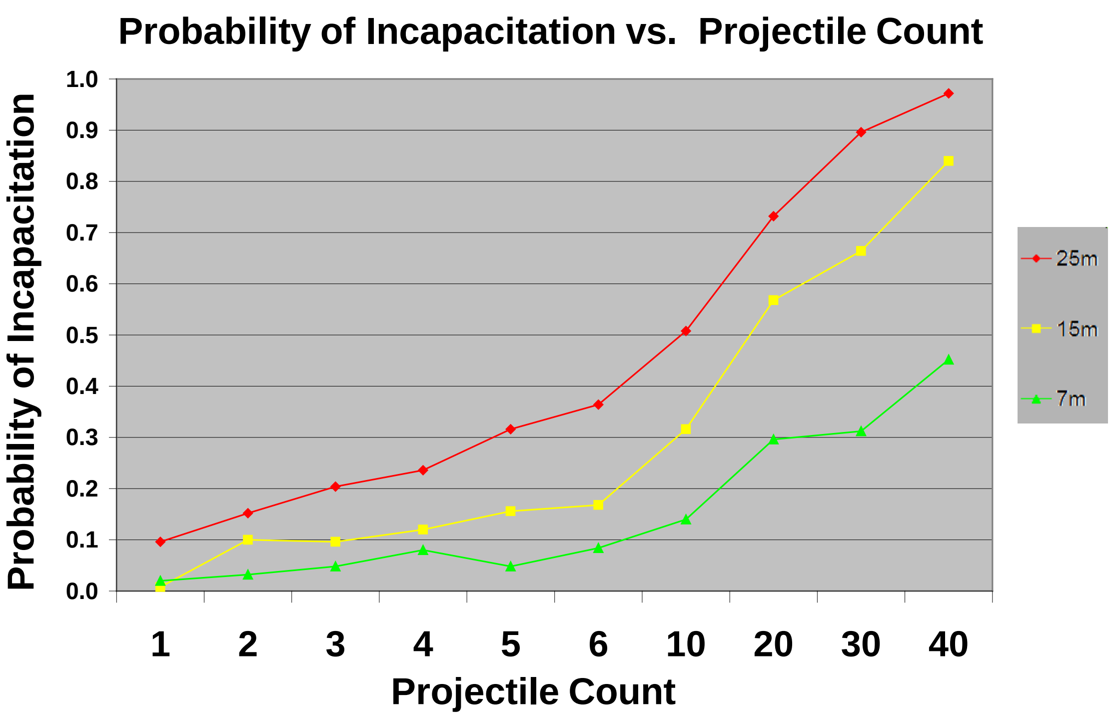
Time Period of Interest: ≤1 second

Job Description Chosen: Armed Adversary

- Most difficult job to incapacitate
  - Pro: Provides worst case scenario
  - Con: May underestimate incapacitation potential of a given round

- Incapacitation is achieved by damaging the central nervous system, cardiovascular system, and the skeletomuscular system
- This job description was approved by Director of Combat Development, Infantry Center
- It was used by ARL in lethality and small arm characterization studies (FY09-Present)

Characterizing a Sample Shot Configuration



Projectiles	1	2	3	4	5	6	10	20	30	40
25 m	.10	.15	.20	.24	.32	.36	.51	.73	.90	.97
15 m	.01	.10	.10	.12	.16	.16	.32	.57	.67	.84
7 m	.02	.03	.05	.08	.05	.08	.14	.30	.31	.45

Probability of P(I) = 1 for given projectile count @ given ranges

Shot Configuration Variables

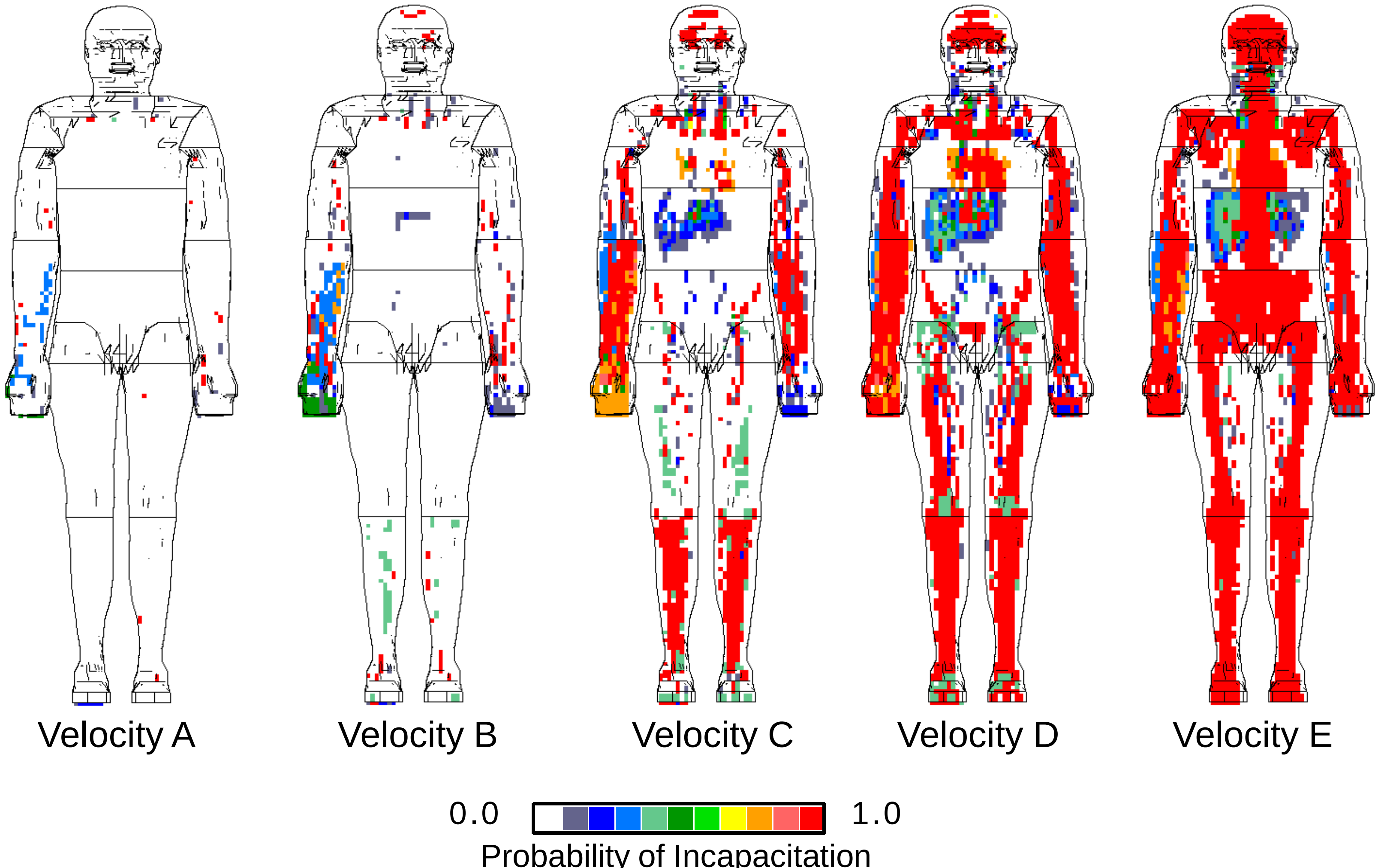
- Mass
- Shape
  - Sphere
  - Cube
  - Cylinder
- Velocity
- Count
- Dispersion Angle
- Material
  - Steel
  - Lead
  - Tungsten

Target Configuration Variables

- Range
- Posture
- Armored vs. Armored
- Job Description

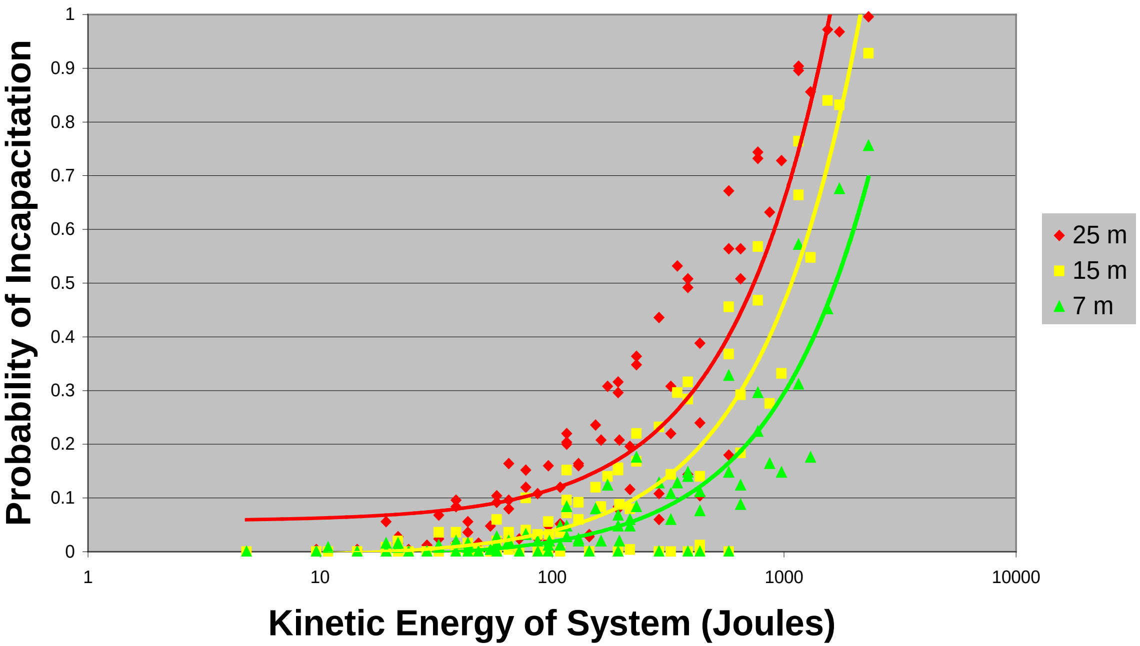
Characterizing a Single Pellet

- These incapacitation plots were modeled using a single projectile from a given shot configuration.
- Uniform grid of shot lines in a front-only view with zero degrees azimuth and elevation.



Optimization Observations

Probability of Incapacitation vs. Kinetic Energy of System



Summary

Without sufficient penetration, an increase in dispersion/pellet count will result in a minimal increase in incapacitation. However, as range increases, dispersion and pellet count amplify a MPC's ability to incapacitate by damaging more than one physiological region at once.

Observations

- Driving factors of incapacitation:
  - Penetration/tissue damage (KE of the system)
  - Hit location (dispersion)
  - Quantity of tissues damaged (pellet count)
- Without sufficient penetration, incapacitation is unlikely regardless of hit location
- With an increase in dispersion, pellet count is a greater factor
- A high energy, optimally dispersed system with the maximum number of projectiles provides the greatest potential for complete incapacitation

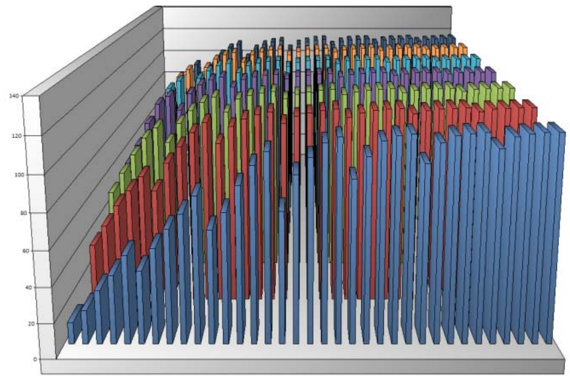
Optimization Analysis

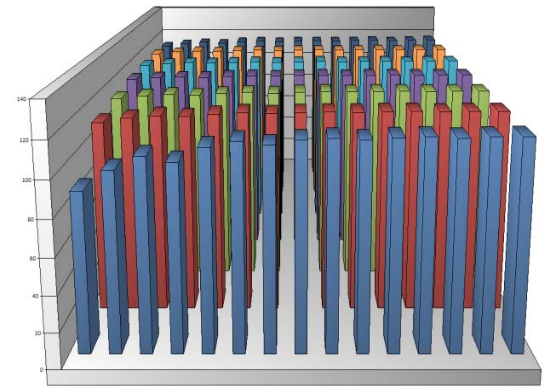
245 Mass/Velocity/Dispersion Configurations

Optimization Methodologies:

- **Trend analysis via frequency histograms**
- **Legacy constraints:**
  - **Velocity**
  - **Mass**
  - **Dispersion**
- **Geometric optimization**

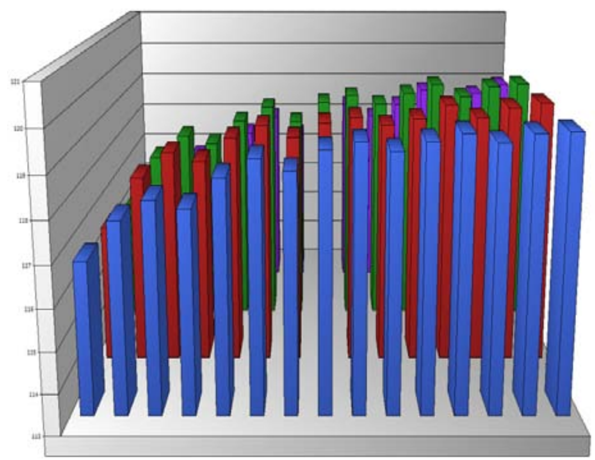
Results: 8 final configurations

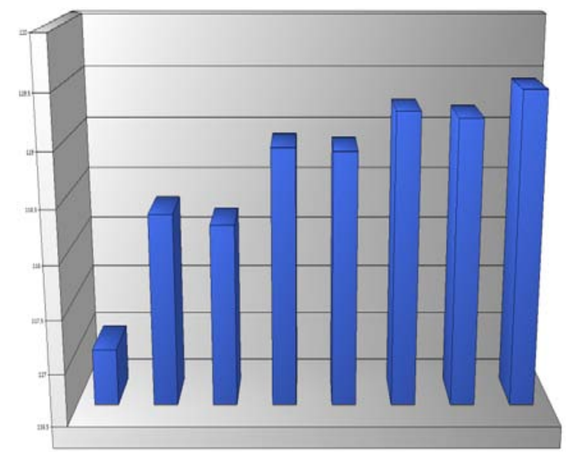




Configurations: 245 → 105 →

Constraint: Projectile Velocity/Mass





→ 45 → 8

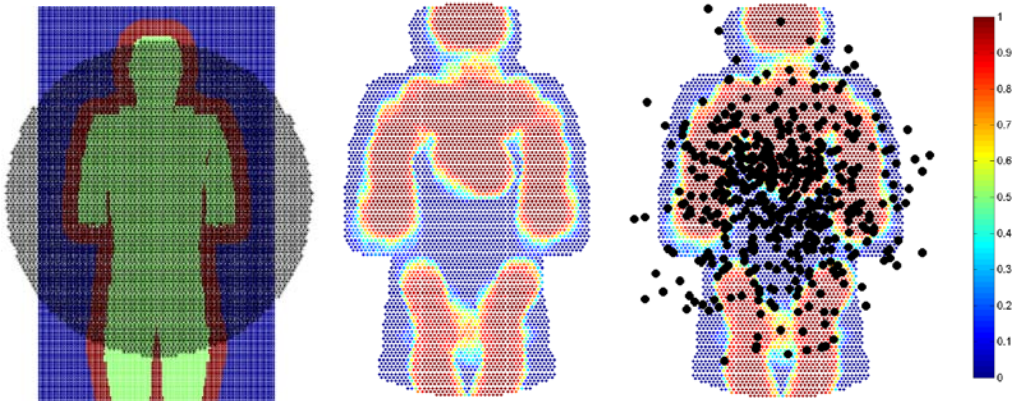
Dispersion — Geometric Optimization

Operational Modeling

MUVES-S2/ORCA provides inputs for dynamic modeling software such as The Infantry Warrior Simulation (IWARS)

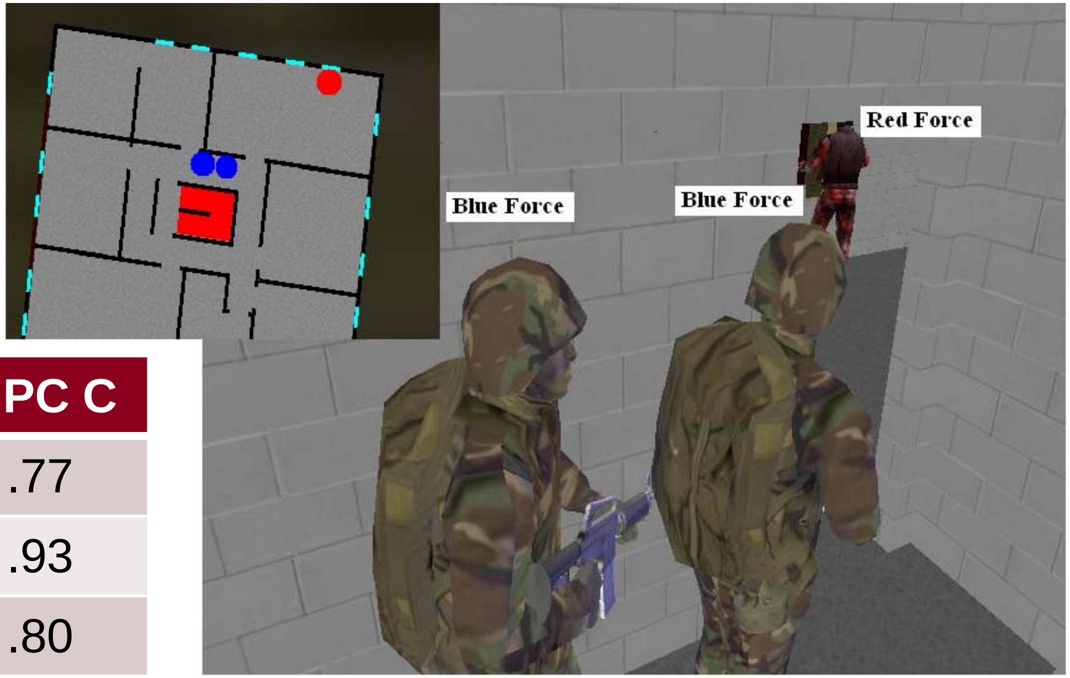
Tailored to the specific analysis:

- Scope
  - System based
  - Single projectile based
- Casualty based P(I) values
  - Entire body
  - Per body region
  - With or without aim error



Images provided by ARL/WMRD

Range	MPC A	MPC B	MPC C
7 meters	.57	.99	.77
15 meters	.69	1	.93
25 meters	.86	1	.80



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Questions

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